

Article

Childhood Trauma and Brainwave Patterns: A qEEG Comparison Between Trauma-Affected and Non-Affected Individuals

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Abstract

Background: Childhood trauma has been associated with long-term neurophysiological alterations; however, evidence in non-clinical populations remains limited. This study investigated differences in brainwave activity between individuals with and without childhood trauma using quantitative electroencephalography (qEEG) in a young adult non-clinical sample. **Methods:** Thirty young adults completed the Childhood Trauma Questionnaire-Short Form (CTQ-SF) and underwent qEEG recording under standardized resting-state conditions, including eyes-closed (EC) and eyes-open (EO). Only resting-state EEG data were included in the final analysis. Principal Component Analysis (PCA) was applied across seven frequency bands (Delta, Theta, Alpha, Low Beta, Beta, High Beta, and Gamma) for dimensionality reduction, followed by independent-sample *t*-tests to examine group differences between participants with no childhood trauma and those with severe childhood trauma. **Results:** Significant group differences were observed in several qEEG-derived components, particularly within the Alpha, Low Beta, Beta, High Beta, and Gamma frequency bands. These differences were most prominent in frontal, central, temporal, and parietal regions, suggesting variations in cortical activation patterns between trauma and non-trauma groups. **Conclusions:** The findings suggest that childhood trauma exposure is associated with distinct patterns of resting-state brainwave activity in young adults without a formal PTSD diagnosis. However, these results should be interpreted as exploratory, and further research with larger and more balanced samples is required to validate these findings and improve generalizability.

Keywords: childhood trauma; qEEG; brainwave dysregulation



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1. Introduction

Approximately 70% of the global population will experience a potential traumatic event in their lifetime [1], and childhood trauma has been identified as one of the factors associated with the later development of affective disorders in both children and adults [2]. It has been estimated that approximately one in six individuals (17.3%) has experienced childhood trauma [3], with some studies reporting a higher prevalence among females compared with males [4]. Childhood trauma may affect psychological well-being by increasing vulnerability to depression, anxiety, emotional instability, and other trauma-related symptoms [5–8]. If the effects of childhood trauma remain unaddressed over time, affected individuals may be at increased risk of developing posttraumatic stress disorder (PTSD) and trauma-related depression [9–11]. However, exposure to trauma does not necessarily lead to PTSD. Koenen and colleagues reported that only 5.6% of individuals

exposed to trauma later developed PTSD, suggesting that trauma exposure and PTSD diagnosis should not be treated as equivalent constructs [12]. Previous studies have examined neurophysiological changes, including the brainwave dysregulation, in individuals with trauma histories. However, much of this research has focused on individuals with clinically diagnosed PTSD or other trauma-related clinical conditions [13–20]. Less attention has been given to individuals who report childhood trauma but do not have a formal PTSD diagnosis. This distinction is important because trauma exposure may be associated with neurophysiological differences even in non-clinical populations [21,22]. Examining individuals without a formal PTSD diagnosis may therefore help clarify whether childhood trauma is associated with measurable differences in brainwave activity outside clinical PTSD samples.

The present study is conceptually informed by the defense cascade model and polyvagal theory. The defense cascade model describes a sequence of physiological responses to perceived threat, including (1) Freeze, (2) Flight, (3) Fight, (4) Fright, (5) Flag, and (6) Faint [23,24]. The polyvagal theory proposes that physiological responses to safety, danger, and life threat are regulated through pathways of the autonomic nervous system (ANS), including the ventral vagal pathway, the sympathetic nervous system, and the dorsal vagal pathway [25]. In trauma-affected individuals, dysregulation of these systems may be associated with heightened sympathetic activation, defensive responding, or dissociative-like coping responses [26]. These physiological patterns may be reflected in altered neural oscillatory activity. For example, trauma or PTSD has been associated with increased Beta activity, which may reflect heightened arousal or stress-related activation [27]. An individual's alertness level may be heightened as they remain in a state of constant fear, which disrupts the fight-or-flight mode [28]. Other studies have suggested that dissociative or freezing responses may be associated with changes in Alpha-Theta activity and temporal Theta activity [29,30].

Quantitative electroencephalography (qEEG) is a non-invasive neurophysiological technique that extends the traditional electroencephalography (EEG) by applying mathematical and statistical methods to quantify the brain's electrical activity [31]. qEEG allows researchers to examine brainwave activity across different frequency bands and scalp regions, which may provide useful information about patterns of cortical activation. In some clinical and research contexts, qEEG data may also be compared with normative reference databases that account for factors such as age and sex [32,33]. qEEG has been used in studies involving attention-deficit/hyperactivity disorder, mood disorders, and schizophrenia by pinpointing the specific brain wave patterns that are associated with these disorders [34–36]. qEEG utilized the 10–20 system, which is a standardized method of placing electrodes on the individual's scalp to record the electrical activity from the brain directly (Jasper, 1958, as cited in [37]). In the present study, qEEG is used as an exploratory research tool to examine whether resting state brainwave patterns differ between individuals with and without childhood trauma.

1.1. Research Gaps and Research Significance

Previous studies have examined brainwave abnormalities and neurophysiological differences in individuals with trauma histories, particularly among those with clinically diagnosed PTSD [13,14,16,20]. However, less is known about whether similar qEEG-related differences can be observed in non-clinical individuals who report childhood trauma but do not have a formal PTSD diagnosis. This distinction is important because trauma exposure does not necessarily lead to PTSD, and trauma-related neurophysiological differences may exist even outside clinically diagnosed populations.

The present study contributes to this literature by examining resting-state qEEG patterns in a young adult non-clinical sample and by comparing two clearly defined childhood trauma severity groups based on the Childhood Trauma Questionnaire-Short Form (CTQ-SF): individuals reporting no childhood trauma and individuals reporting severe childhood trauma. By focusing on these two severity extremes, this study provides an exploratory comparison of whether childhood trauma exposure is associated with measurable differences in brainwave activity. This approach may help clarify whether qEEG-derived neural activity patterns differ between individuals with severe trauma exposure and those without reported trauma exposure.

qEEG may be a complementary research tool in trauma-related assessment because it provides temporally sensitive information about neural oscillatory activity [31]. When used together with self-report measures, qEEG may offer additional information about neurophysiological patterns that cannot be captured through questionnaires alone. This is relevant because self-report trauma measures may be influenced by recall bias, minimization, denial, emotional state, and cultural interpretation [20,38,39].

1.2. The Objectives

The objective of the present study was to examine whether young adults with severe childhood trauma exposure differ from young adults with no reported childhood trauma in resting-state qEEG-derived brainwave patterns. Childhood trauma exposure was assessed using the CTQ-SF, and participants were classified into no-trauma and severe-trauma groups based on established CTQ-SF severity criteria. Given the small sample size and exploratory nature of the study, the findings are intended to provide preliminary evidence for future research rather than to establish causal relationships or diagnostic biomarkers.

2. Literature Review

Understanding the brainwave activity in the context of childhood trauma is essential for examining possible associations between trauma exposure and neurophysiological differences. Previous studies have suggested that individuals with a history of childhood trauma may exhibit altered brainwave patterns across several frequency bands, including Delta, Theta, Alpha, Beta, and Gamma, particularly in brain regions associated with emotional regulation, memory processing, and stress response [14,40–44]. However, the findings across studies are not entirely consistent, and differences in sample characteristics, trauma classification, qEEG procedures, and statistical approaches may contribute to variation in the reported results.

Lee and colleagues examined the relationship between childhood trauma and EEG band power using qEEG in 157 healthy Korean adult volunteers aged between 19 and 46 years [43]. Participants were divided into a high CTQ-SF group and a low CTQ-SF group based on their CTQ-SF scores. The study reported that participants with higher CTQ-SF scores showed increases in their Delta, Beta, and Gamma band power, together with decreased low-Alpha power in anterior regions (Fp1, F3, F7, Fz, Fp2, F4, and F8). Elevated Beta and Gamma band power were also reported in middle regions (T7, C3, Cz, T8, and C4), as well as in posterior regions (P7, P3, O1, Pz, P8, P4, and O2). These findings suggest that higher childhood trauma scores may be associated with altered neural oscillatory activity across frontal, central, temporal, and posterior regions.

Another study by Marcu and colleagues has conducted a case report to investigate the effects of complex childhood trauma on brain functioning in maltreated adolescents using qEEG [45]. The study included two half-siblings and two non-identical twins and identified brainwave differences in regions associated with sensory processing, attention, and cognitive control. In particular, differences in Theta and Beta power were observed

in central regions (Fz, Cz, and Pz). A decrease in Alpha power was also reported in the posterior regions (O1 and O2). These findings were interpreted as indicating possible alterations in sensory processing and attentional control among trauma-affected adolescents. In addition, Laney and Nooner also examined functional brain changes associated with childhood trauma using qEEG [46]. Their study included 52 adolescents aged between 12 and 14 years, most of whom had documented childhood trauma histories. The study reported altered Alpha power among individuals with childhood trauma, particularly increased Alpha power in frontal (Fz), central (Cz), and parietal (Pz) regions, reflecting lower cortical activation or altered attentional functioning.

Howells and colleagues investigated the association between childhood trauma and cortical arousal, using qEEG. They recruited 53 healthy adult participants (22 males and 31 females, with a mean age of 27 years). Participants had no reported history of psychiatric or substance use disorders, no psychoactive medication use, or medical conditions related to brain trauma. The study found that childhood trauma was associated with decreased Alpha power in the left parietal cortex (P3), right frontal cortex (F4), and left frontal cortex (F3). Interestingly, the study also reported that denial scores were associated with decreased Beta power in the left frontal region (F3) and increased Alpha power in the right frontal region (F4).

In contrast, Jin and colleagues examined the relationship between childhood trauma and brainwave activity using qEEG in 103 participants and did not find a significant association between childhood trauma and brain activity [42]. This finding indicates that the relationship between childhood trauma and qEEG-derived brainwave patterns may not be uniform across samples.

Hypothesis

It is hypothesized that young adults with severe childhood trauma exposure would show significant differences in resting-state qEEG-derived neural activity components compared with young adults reporting no childhood trauma, as assessed by the CTQ-SF.

3. Methodology

3.1. Research Design

This study employed a quantitative, cross-sectional, exploratory group-comparative design, which involves the systematic collection and analysis of numerical data at a single point in time to provide a snapshot of the study population, while allowing a flexible investigation of broad research questions to uncover new insights and examine associations between variables [47–49]. The study compared resting-state qEEG-derived brainwave patterns between two groups of young adults: individuals reporting no childhood trauma and individuals reporting severe childhood trauma. Participants were not randomly assigned to groups. Instead, they were classified into groups based on their CTQ-SF scores. Therefore, the study should be understood as observational and group-comparative rather than experimental or causal in design. This design allowed the study to examine whether childhood trauma group status was associated with differences in resting-state qEEG-derived neural activity, but it does not allow conclusions about causality.

The CTQ-SF was used to classify participants according to childhood trauma severity. qEEG recording was then used to obtain quantitative neurophysiological data on resting-state brainwave activity across different frequency bands and scalp regions. Together, these measures enabled the study to explore associations between childhood trauma exposure and qEEG-derived neural activity patterns in a non-clinical young adult sample.

3.2. Participants

The targeted population for this study consisted of young adults with and without reported childhood trauma, as assessed using the CTQ-SF. Participants were classified into two groups. The first group consisted of individuals with severe trauma exposure (indicated by high CTQ-SF scores, categorized as “severe” group), and the second group consisted of individuals with no reported trauma exposure (indicated by low CTQ-SF scores, categorized as “none” group).

The inclusion criteria were established to ensure that the sample was consistent with the study objective and to reduce potential sources of variability that could affect qEEG data. Participants were required to meet the following criteria:

- i. Participants must be Asian citizens.
- ii. Participants must have at least basic proficiency in English.
- iii. Participants must be young adults (18–30 years old), consistent with previous childhood trauma research that predominantly recruited participants within this age range [50–52]. Restricting the sample to young adults also helped reduce age-related variability in neural activity, as different age groups may show different patterns of brain activation [53–55].
- iv. Participants must have either no reported childhood trauma or severe trauma as determined by CTQ-SF severity criteria. The cut-off scores used to determine “none” and “severe” levels of childhood trauma severity are presented in Table 1.

Table 1. The cutoff scores for CTQ-SF.

Level of Severity	Emotional Abuse	Physical Abuse	Sexual Abuse	Emotional Neglect	Physical Neglect
None	8	7	5	9	7
Low	12	9	7	14	9
Moderate	15	12	12	17	12
Severe	16+	13+	13+	18+	13+

Participants were excluded if they reported a clinically diagnosed neurological or psychiatric disorder. This exclusion criterion was applied because such conditions may influence brainwave activity and potentially confound the interpretation of qEEG findings.

A two-phase recruitment strategy was used. In Phase 1, convenience sampling was used to recruit potential participants. Convenience sampling is a non-probability sampling method that involves recruiting individuals who are accessible to the researcher [56,57]. Participants were recruited through social media platforms, including Facebook and Instagram, as well as through student communities, email invitations, and promotional materials distributed around campus. These recruitment channels were selected because they provided access to individuals who were likely to meet the study’s target characteristics, including age range, English proficiency, and demographic background.

In Phase 2, participants who completed the initial CTQ-SF screening were assessed for eligibility based on the inclusion and exclusion criteria. Participants whose CTQ-SF scores fell within the “none” or “severe” range and who did not report any clinically diagnosed neurological or psychiatric disorder were invited to participate in the qEEG recording session. Participants with low or moderate childhood trauma scores were not included in the final qEEG comparison because the study focused specifically on comparing two clearly defined trauma severity extremes.

The final sample size was determined based on a previous qEEG study conducted by Jahan and colleagues [58]. They also employed a comparative analysis, specifically comparing male and female participants, with 15 individuals in each group. Given

the methodological similarities, particularly the use of the qEEG to compare different groups, the present study adopted the same sample size as that used by Jahan and colleagues—a total of 30 participants, evenly divided into 15 participants in each group. However, unlike Jahan and colleagues, who compared male and female participants, the present study compares individuals with no childhood trauma and those with severe childhood trauma, as classified according to CTQ-SF scores.

3.3. Psychological Measures

The CTQ-SF was used to assess the severity level of an individual's childhood traumatic experience. It includes 28 items, each rated on a 5-point Likert scale, with 1 = Never True, 2 = Rarely True, 3 = Sometimes True, 4 = Often True, and 5 = Very Often True. It is to quantify the severity of trauma, covering various forms of childhood trauma, including emotional abuse, physical abuse, sexual abuse, emotional neglect, and physical neglect [59]. Bernstein and Fink have defined the cut-off scores for the CTQ-SF, which categorize childhood trauma exposure levels into “none”, “low”, “moderate”, and “severe”, where higher scores indicate greater trauma severity [60]. According to MacDonald and colleagues, individuals with a total score of ≤ 36 on the CTQ-SF score will be categorized as “none” in terms of childhood trauma experience, while those with a score of ≥ 69 will be classified as “severe” in childhood trauma severity [61]. Participants with scores between 37 and 51 will be categorized as having “low” in childhood trauma severity, and those with scores between 52 and 68 will be classified as “moderate” level. Additionally, participants who score more than 1 on the minimization and denial scale will be excluded from the study to avoid potential biases.

3.4. qEEG Analysis

Before qEEG recording, participants completed an online questionnaire that collected basic demographic and screening information required for brain mapping and data processing. The questionnaire data were used together with the EEG recording files in the Trainer's Q software (TQ 8 version) system for qEEG processing.

qEEG recording was conducted in a controlled environment and lasted approximately one to two hours. Brainwave data were recorded using the standardized 10–20 electrode placement system. The electrode sites included Fp1, Fp2, Fz, F3, F4, F7, F8, T3, T4, T5, T6, Cz, C3, C4, Pz, P3, P4, Oz, O1, and O2. During the recording session, participants were instructed to remain still and relaxed and to minimize unnecessary movement to reduce potential artifacts.

Resting-state recordings were obtained under two standardized conditions: eyes-closed (EC) and eyes-open (EO). The EC condition was used to capture baseline cortical activity in the absence of visual input, while the EO condition was used to assess brain activity under minimal visual stimulation. Both EC and EO conditions are commonly used in qEEG research to examine resting-state neural oscillatory activity.

Although the broader qEEG protocol included task-based cognitive activation procedures, such as reading, listening, imagination, memory recall, and visual attention tasks, these task-based data were not included in the final analysis. Only resting-state EC and EO qEEG data were analyzed in order to maintain consistency in the interpretation of resting-state brainwave activity.

3.5. Statistical Analysis

Data analysis was conducted using IBM SPSS Statistics version 26. Descriptive statistics were first used to summarize participants' demographic characteristics and CTQ-SF scores. Group-wise descriptive statistics were calculated for the no-trauma and severe-trauma groups.

Principal Component Analysis (PCA) was used as an exploratory dimensionality-reduction procedure to reduce the number of qEEG variables before group comparison [62]. PCA was conducted across the qEEG frequency bands, including Delta, Theta, Alpha, Low Beta, Beta, High Beta, and Gamma. The purpose of PCA was to identify data-driven components representing patterns of shared variance across electrode sites within each frequency band. PCA was employed solely as an exploratory data-reduction technique to simplify the high-dimensional qEEG dataset before group comparisons. The retained components were not intended to represent latent neurophysiological or psychological constructs but rather statistical summaries of correlated electrode activity within each frequency band. Accordingly, the PCA results should be interpreted as exploratory. Additionally, independent-samples *t*-tests were used to compare qEEG-derived component scores between the no-trauma and severe-trauma groups.

4. Results

4.1. Participant Flow and Sample Characteristics

A total of 129 individuals were initially recruited in the first phase of the study through a convenience sampling approach. Following screening using the Childhood Trauma Questionnaire-Short Form (CTQ-SF), 47 participants were identified as eligible for inclusion, meeting the criteria for either the “no trauma” or “severe trauma” groups based on CTQ-SF cut-off scores. Of these, 12 participants were excluded due to scoring above 1 on the denial/minimization scale. An additional five eligible participants subsequently withdrew from the study prior to qEEG data collection. Consequently, the final sample comprised 30 participants, evenly allocated into two groups: 15 in the no-trauma group and 15 in the severe childhood trauma group. A participant flow chart is presented below (see Figure 1).

A total of 30 participants were selected and underwent the qEEG data collection for this study. The sample consisted of 4 males (13.3%) and 26 females (86.7%). All participants were Asian citizens and were aged between 18 and 29 years. The most common ages were 20 and 22 years, with each age group representing 16.7% of the sample ($n = 5$ each). In terms of ethnicity, most participants were Chinese (73.3%; $n = 22$), followed by Indian (16.7%; $n = 5$), Malay (6.7%; $n = 2$), and Native participants (3.3%; $n = 1$).

Participants’ highest education levels were also recorded. The largest group held a diploma or technical certificate (40.0%; $n = 12$), followed by a bachelor’s degree (33.3%; $n = 10$), secondary education (20.0%; $n = 6$), foundation-level education (3.3%; $n = 1$), and a master’s degree (3.3%; $n = 1$). Most participants were students or not in paid employment at the time of data collection (73.3%; $n = 22$), while 26.7% were employed in either the private or government sector ($n = 8$).

The overall mean CTQ-SF score was 54.23 (SD = 23.30), with scores ranging from 27 to 92. Group-wise CTQ-SF descriptive statistics for the no-trauma and severe-trauma groups are presented in Table 2. Independent-samples *t*-tests and Chi-square tests indicated no statistically significant differences between the no-trauma and trauma groups in age, gender, ethnicity, education level, or occupation (all $p > 0.05$). These findings suggest that the two groups were generally comparable with respect to their demographic characteristics.

Table 2. Demographic characteristics by study group.

Characteristic		No Trauma ($n = 15$)	Trauma ($n = 15$)	Test Statistics	<i>p</i>
Age (years), Mean $\pm$ SD		22.40 $\pm$ 2.44	22.60 $\pm$ 3.14	$t(28) = -0.20$	0.847
Gender, n (%)	Male	2 (13.3)	2 (13.3)	$\chi^2(1) = 0.00$	1.000
	Female	13 (86.7)	13 (86.7)		

Table 2. Cont.

Characteristic		No Trauma (n = 15)	Trauma (n = 15)	Test Statistics	p
Ethnicity, n (%)	Chinese	12 (80.0)	10 (66.7)	$\chi^2(3) = 1.38$	0.710
	Bumiputera	0 (0.0)	1 (6.7)		
	Malay	1 (6.7)	1 (6.7)		
	Indian	2 (13.3)	3 (20.0)		
Education, n (%)	Bachelor's degree	5 (33.3)	5 (33.3)	$\chi^2(4) = 2.67$	0.615
	Diploma/Technical certificate	6 (40.0)	6 (40.0)		
	Secondary school	2 (13.3)	4 (26.7)		
	Master's degree	1 (6.7)	0 (0.0)		
	Foundation	1 (6.7)	0 (0.0)		
Occupation, n (%)	Student	11 (73.3)	11 (73.3)	$\chi^2(2) = 1.14$	0.565
	Private sector employee	3 (20.0)	4 (26.7)		
	Government employee	1 (6.7)	0 (0.0)		

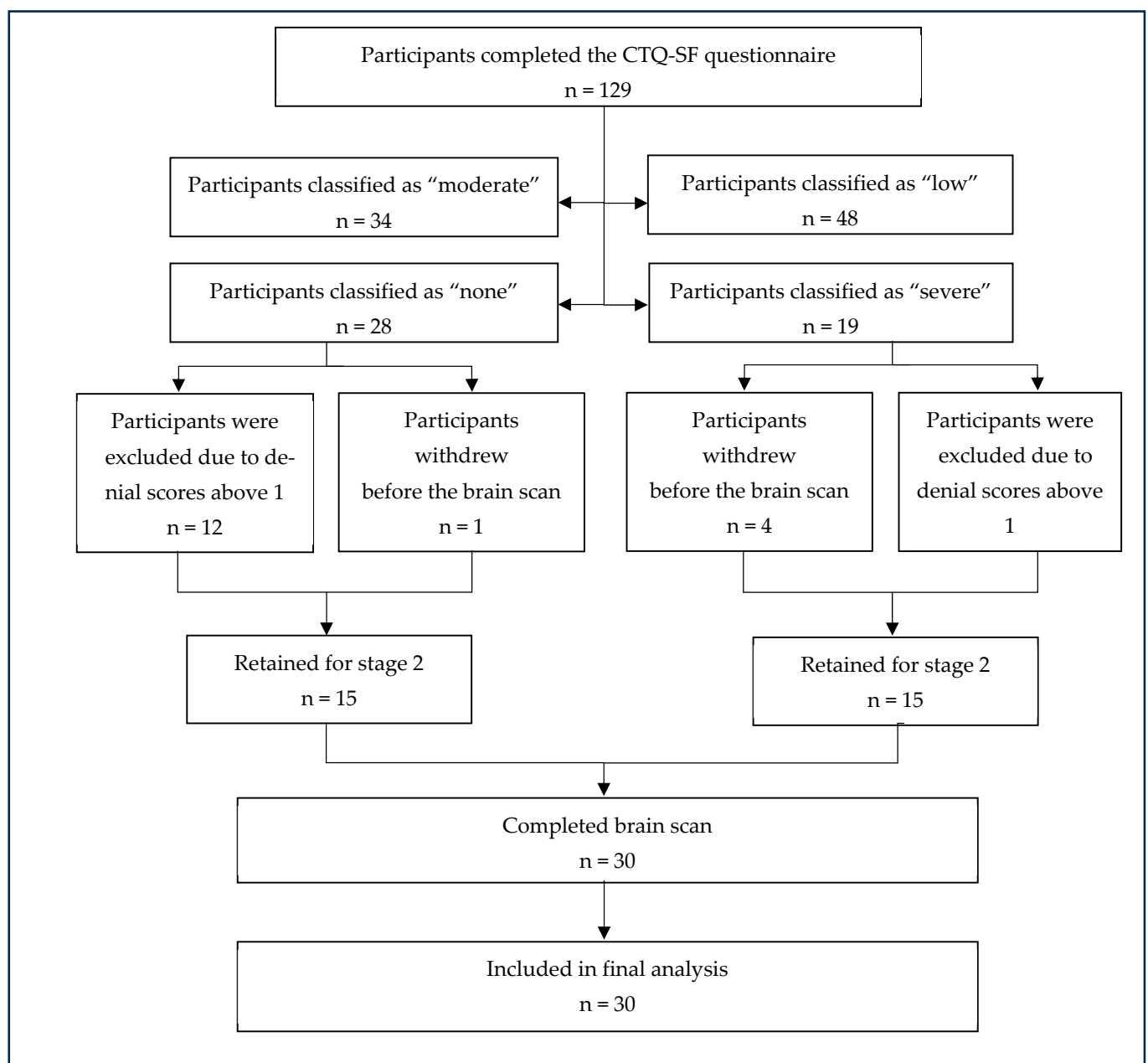


Figure 1. Participant flow chart.

4.2. PCA Components Extraction

Principal Component Analysis (PCA) was used as an exploratory dimensionality-reduction technique to identify component structures within the qEEG dataset. The PCA was conducted separately for each frequency band, namely Delta, Theta, Alpha, Low Beta, Beta, High Beta, and Gamma. This segmented approach was used because the qEEG variables were organized according to band power, allowing component structures to be examined within each frequency band.

Components were retained based on the cumulative variance explained. A cumulative variance threshold of approximately 75% was used as a practical guideline to retain components that accounted for a substantial proportion of variance within each frequency band. This threshold was used to support exploratory data reduction, rather than to establish definitive neurophysiological constructs. Components beyond this threshold were not interpreted in order to avoid over-extraction and unstable low-variance components.

Based on this approach, four components were retained for the Delta, High Beta, and Gamma bands; three components were retained for the Beta band; and two components were retained for the Theta, Alpha, and Low Beta bands. The cumulative variance explained by the retained components is presented in Table 3. The component loading matrices for each frequency band are presented in Table 4. Loadings below 0.40 were suppressed for clarity, while loadings of 0.40 and above were retained because they are commonly considered meaningful in exploratory component interpretation [63,64].

Table 3. The cumulative percentage table.

Components	Band Power (%)						
	Delta	Theta	Alpha	Low Beta	Beta	High Beta	Gamma
1	59.26	63.66	66.10	64.73	54.37	42.14	43.86
2	65.20	70.47	75.00	71.88	65.37	58.78	61.66
3	70.07	-	-	-	72.63	66.93	68.93
4	74.24	-	-	-	-	72.73	74.80

Note. Components with a cumulative percentage below 75% were extracted for further interpretation, while those exceeding 75% were excluded in accordance with Privitera [10].

The functional interpretation of the retained PCA components is presented in Table 5. These interpretations should be treated as tentative and exploratory. The components represent statistical groupings of qEEG variables and should not be interpreted as definitive neural mechanisms, diagnostic indicators, or direct evidence of specific psychological states.

4.3. Assumption Testing

Assumption checks were conducted before performing both analyses. This study meets the first assumption of an appropriate sample size between groups for the independent-samples *t*-test, as each participant in both groups has an equal sample size ($n = 15$). The second and third assumptions for the independent-samples *t*-test were shown in the section below. The second assumption of multivariate normality of dependent variables within each group was evaluated using Q-Q plots, which were points that aligned closely with a straight line, indicating multivariate normality, while points that deviated from the line suggested a departure from normality [65]. The third assumption, homogeneity of covariance matrices, can be assessed using Levene's test ($p \geq 0.05$), in which the Levene's test significant value needs to be more than 0.05 in order to indicate that the assumption of equal covariance matrices across groups is satisfied [63].

Table 4. Pattern matrix for all band powers.

Electrode		Delta				Theta		Alpha		Low Beta		Beta			High Beta				Gamma			
		C1	C2	C3	C4	C1	C2	C1	C2	C1	C2	C1	C2	C3	C1	C2	C3	C4	C1	C2	C3	C4
Fp1	EC	–	0.757	0.338	–	0.585	0.213	–	0.755	–	0.620	0.624	0.407	–	–	–	0.765	–	–	0.854	–	0.269
	EO	–	0.543	0.402	–	–	0.465	0.466	–	–	0.668	0.298	0.428	–	–	–	0.796	–	–	0.748	–	0.328
Fp2	EC	–	0.743	0.333	–	0.679	–	–	0.725	–	0.462	0.582	0.465	–	–	–	0.782	–	–	0.862	–	0.231
	EO	–	0.590	0.352	–	0.413	–	0.422	–	–	0.514	0.514	–	–	–	–	0.740	–	–	0.894	–	0.178
F7	EC	–	–	–	–	–	–	–	0.606	–	–	–	–	0.978	0.994	–	–	–	0.990	–	–	–
	EO	–	–	–	–	–	–	0.818	–	–	–	–	–	0.995	1.000	–	–	–	0.982	–	–	–
F3	EC	0.661	–	–	–	0.913	–	–	0.730	0.487	0.558	0.866	–	–	0.803	–	–	–	0.498	0.428	–	–
	EO	0.534	–	–	–	0.279	0.600	0.960	–	0.730	–	0.788	–	–	0.734	–	–	–	0.538	0.419	–	–
Fz	EC	–	0.999	–	–	0.406	–	–	0.766	–	–	–	–	0.876	0.973	–	–	–	0.938	–	–	–
	EO	0.662	0.576	–	–	–	–	0.862	–	–	–	–	–	0.981	1.023	–	–	–	0.974	–	–	–
F4	EC	–	–	–	–	0.742	–	–	0.799	0.261	0.571	0.700	–	0.401	0.559	0.671	–	–	0.846	–	–	–
	EO	–	–	–	–	–	0.654	0.989	–	0.559	–	0.591	–	0.387	0.420	0.682	–	–	0.860	–	–	–
F8	EC	1.056	–	–	–	–	–	–	0.687	–	0.318	–	0.273	0.889	0.945	–	–	–	0.987	–	–	–
	EO	–	–	–	–	–	–	0.728	–	–	0.183	–	0.456	0.708	0.827	–	–	–	0.963	–	–	–
T3	EC	–	–	0.906	–	0.808	–	–	0.307	0.539	0.507	0.402	0.357	–	–	–	0.457	–	–	0.443	0.390	–
	EO	–	–	0.858	–	0.367	0.687	0.903	–	0.822	–	–	–	–	–	–	–	0.487	–	0.340	0.440	–
C3	EC	0.520	–	0.415	–	0.762	–	–	0.573	–	0.866	0.833	–	–	0.592	–	0.522	–	–	0.538	0.484	–
	EO	0.759	–	–	–	0.209	0.752	0.893	–	0.582	0.338	0.984	–	–	0.861	–	–	–	–	0.629	0.461	–
Cz	EC	0.480	0.371	–	–	0.834	–	–	0.712	–	0.729	0.906	–	–	0.828	–	–	–	–	0.841	–	–
	EO	0.927	–	–	–	0.473	0.347	0.911	–	0.643	–	0.873	–	–	0.764	–	–	–	–	0.797	–	–
C4	EC	0.406	0.356	–	–	0.864	–	–	0.526	–	0.843	0.579	0.374	–	0.466	–	–	0.128	–	–	0.666	0.230
	EO	0.654	0.270	–	–	0.189	0.582	0.937	–	0.519	0.340	0.744	–	–	0.670	–	–	0.200	–	–	0.638	0.367
T4	EC	–	–	0.779	–	0.901	–	–	0.314	0.433	–	–	0.556	–	–	–	–	0.776	–	0.408	0.446	0.299
	EO	0.483	–	0.505	–	0.439	0.311	0.922	–	0.650	–	–	–	–	–	–	–	0.931	–	0.287	0.341	0.265
T5	EC	–	0.515	0.534	0.371	0.806	–	–	0.834	–	0.281	–	0.954	–	0.858	0.589	–	0.569	0.858	–	–	0.281
	EO	–	–	–	0.591	–	–	0.550	–	–	–	–	0.668	0.427	0.898	0.740	–	0.574	0.898	–	–	0.269
P3	EC	0.449	0.230	–	–	0.658	0.410	–	0.988	–	0.929	0.666	0.444	–	0.849	–	–	–	–	–	0.981	–
	EO	0.524	0.247	–	–	0.134	0.706	0.895	–	0.387	–	0.931	–	–	0.962	–	–	–	–	–	0.970	–
Pz	EC	0.507	0.479	–	–	0.694	–	–	0.978	–	0.879	0.795	0.263	–	0.776	–	–	0.327	–	–	0.513	0.494
	EO	0.905	–	–	–	0.250	0.440	0.798	–	0.354	–	0.857	–	–	0.722	–	0.334	0.290	–	–	0.504	0.529
P4	EC	0.684	–	–	–	0.735	0.358	–	0.837	–	1.025	0.735	0.310	–	0.904	–	–	–	–	–	0.754	–
	EO	0.891	–	–	–	0.235	0.766	0.930	–	0.494	–	1.015	–	–	0.961	–	–	–	–	0.233	0.542	–
T6	EC	0.282	0.328	–	–	0.839	–	–	0.380	–	0.482	–	0.813	–	–	0.385	–	0.477	0.405	0.385	–	0.477
	EO	–	–	0.623	0.350	0.359	–	0.512	–	–	–	0.636	0.365	0.687	–	–	–	0.425	0.687	0.176	–	0.425
O1	EC	–	–	0.384	0.395	0.630	–	–	0.875	–	0.591	0.296	0.843	–	–	–	0.791	0.220	–	0.414	–	0.620
	EO	–	–	–	0.549	–	0.340	0.760	–	–	–	0.269	0.713	–	–	–	0.897	–	–	0.613	–	0.354
Oz	EC	–	0.399	0.421	–	0.735	–	–	0.840	0.501	0.497	0.501	0.497	–	0.504	–	–	0.530	–	–	0.343	0.531
	EO	0.837	–	–	0.203	–	0.645	0.798	–	0.451	–	0.512	–	–	0.463	–	–	0.597	–	–	0.517	0.504
O2	EC	–	–	–	0.707	0.508	–	–	0.294	–	0.579	0.290	0.794	–	–	–	0.580	0.335	–	–	–	0.744
	EO	–	–	–	0.555	–	0.425	0.785	–	–	–	0.328	0.684	–	–	–	0.769	0.153	–	–	–	0.734

Note. The locations of electrodes are derived based on the 10–20 system; EC = eyes-closed state; EO = eyes-open state.

Table 5. Levene’s test based on means for all the band powers.

Band Power	Component	Levene Statistic	df1	df2	Sig.
Delta	1	0.158	1	28	0.694
	2	1.139	1	28	0.295
	3	1.135	1	28	0.296
	4	0.604	1	28	0.444
Theta	1	0.017	1	28	0.899
	2	1.173	1	28	0.288
Alpha	1	3.439	1	28	0.074
	2	0.622	1	28	0.437
Low Beta	1	4.134	1	28	0.052
	2	0.081	1	28	0.779
Beta	1	6.588	1	28	0.016
	2	1.129	1	28	0.297
	3	5.319	1	28	0.029
High Beta	1	1.938	1	28	0.175
	2	4.577	1	28	0.041
	3	0.223	1	28	0.641
	4	0.321	1	28	0.576
Gamma	1	4.442	1	28	0.044
	2	0.359	1	28	0.554
	3	0.653	1	28	0.840
	4	3.167	1	28	0.086

The assumption of multivariate normality was assessed using Q-Q plots, and the Q-Q plots for the Delta (see Figure 2), Theta (see Figure 3), Alpha (see Figure 4), Low Beta (see Figure 5), Beta (see Figure 6), and High Beta bands (see Figure 7) were presented individually based on the band power in the figures below. They show that the data for both the trauma and control groups were approximately normally distributed with only minor deviations at the extreme. However, the Q-Q plots for the Gamma band show that the data for the trauma groups exhibit significant deviations, which indicate a non-normal distribution, while the control groups show approximately a normal distribution, with minor deviations observed at the extreme (see Figure 8). Thus, the assumption for the Gamma band was considered not fulfilled.

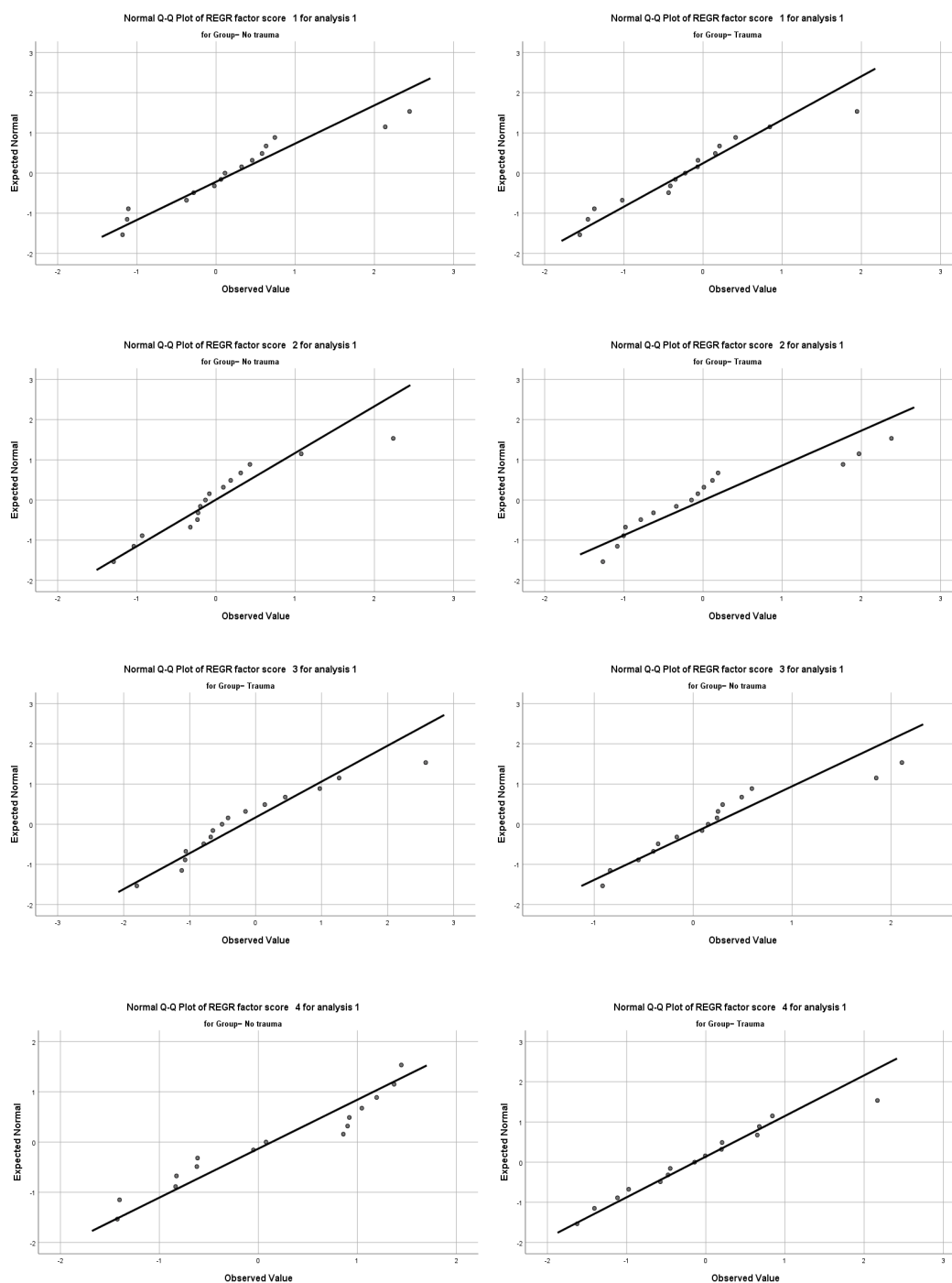


Figure 2. Q-Q plots of four components in the Delta band for both the control and trauma groups.

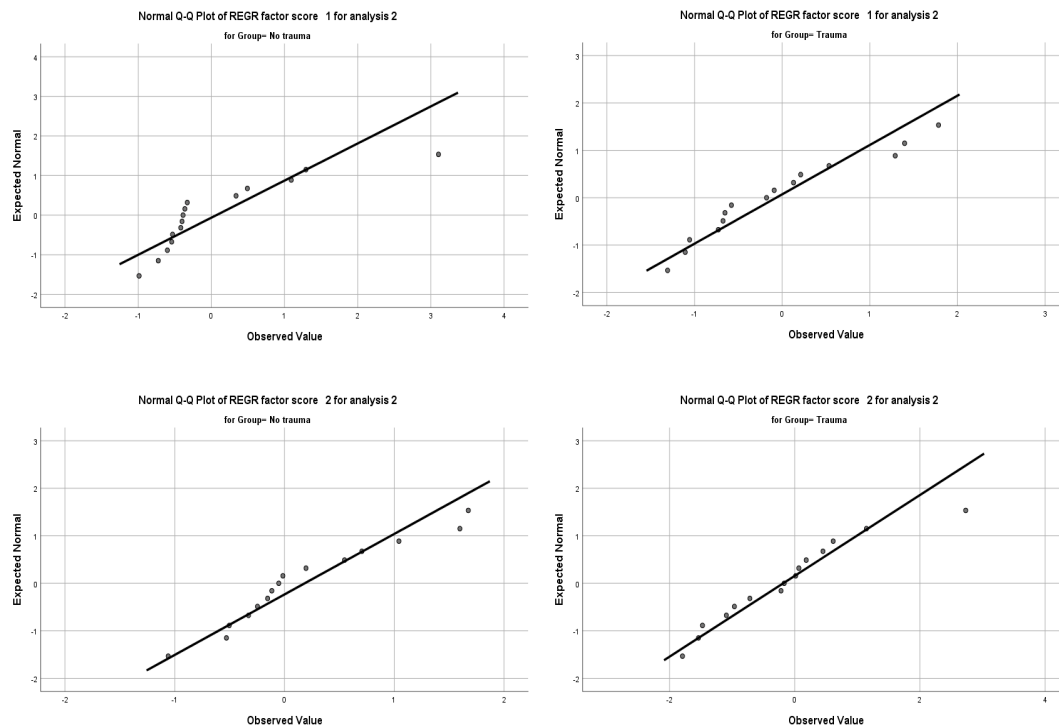


Figure 3. Q-Q plots of four components in the Theta band for both the control and trauma groups.

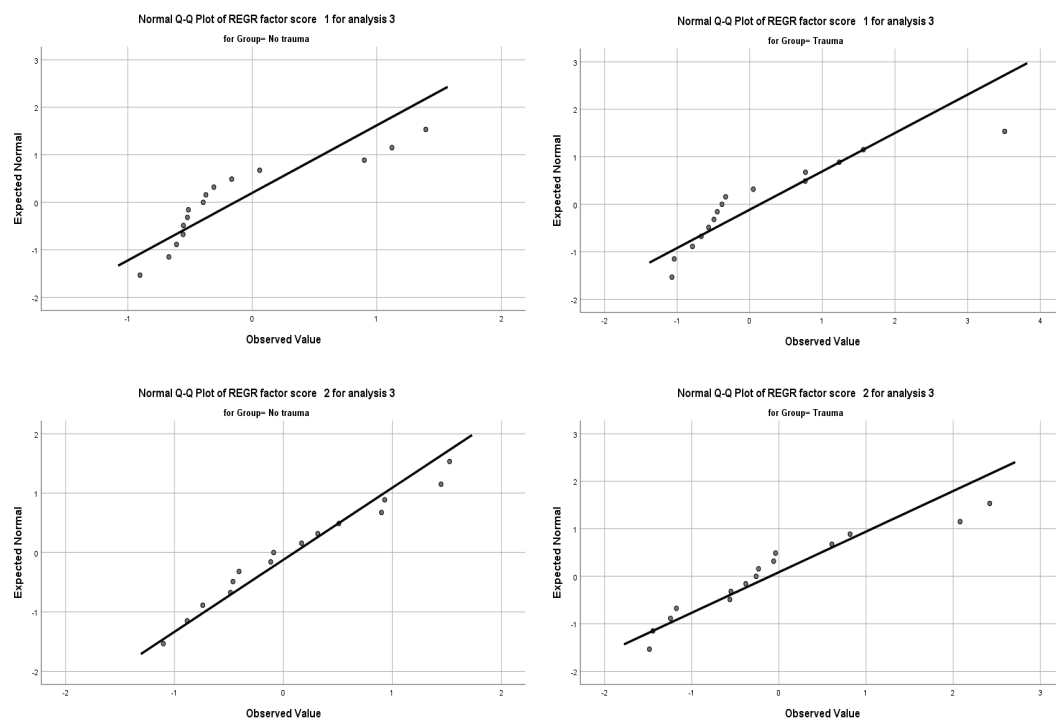


Figure 4. Q-Q plots of four components in the Alpha band for both the control and trauma groups.

The assumptions of homogeneity of the covariance matrices assessed by Levene's test were shown in Table 5. The results for the p -value of all the components in Delta, Theta, and Alpha, and Low Beta were non-significant, which indicates an equal covariance matrix across groups; while only component 2 in Beta, components 1, 3, and 4 in High Beta, and components 2, 3, and 4 in Gamma band have fulfilled the assumptions of an equal covariance matrix. However, the results for components 1 (Levene's $F(1, 28) = 6.588$, $p \leq 0.05$) and 3 (Levene's $F(1, 28) = 5.319$, $p \leq 0.05$) in Beta, component 2 (Levene's $F(1, 28) = 4.577$,

$p \leq 0.05$) in High Beta, and component 1 in Gamma (Levene's $F(1, 28) = 4.442$, $p \leq 0.05$) yield significant results, indicating non-covariance matrices across groups.

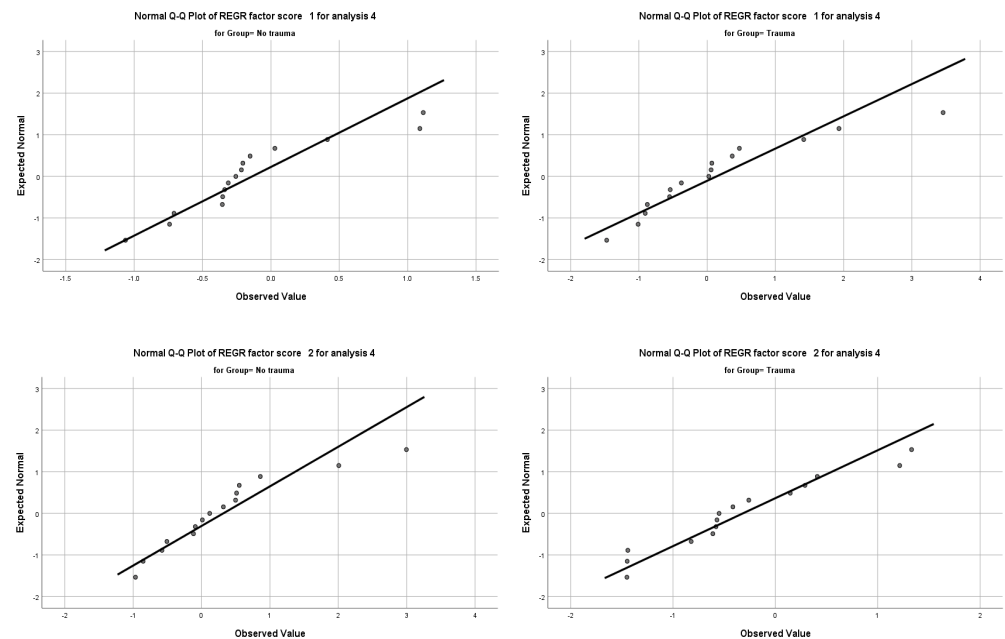


Figure 5. Q-Q plots of four components in the Low Beta band for both the control and trauma groups.

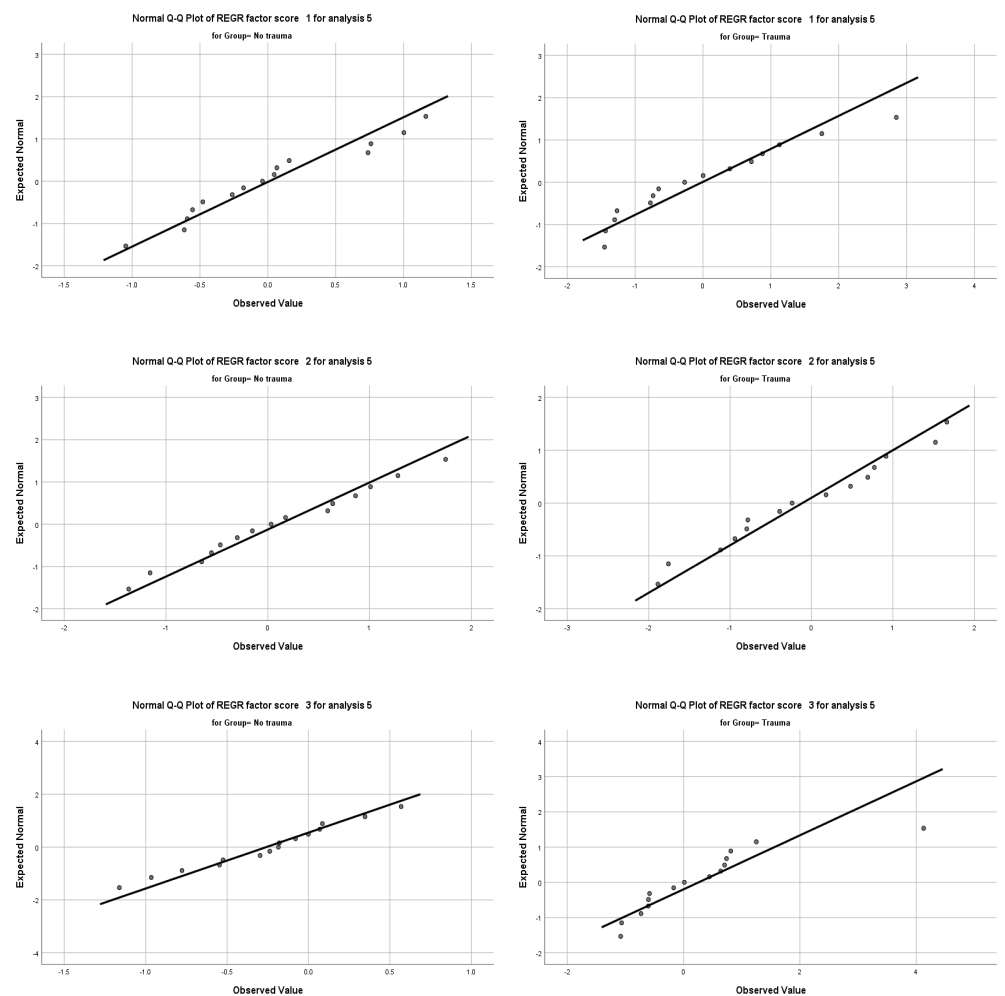


Figure 6. Q-Q plots of four components in the Beta band for both the control and trauma groups.

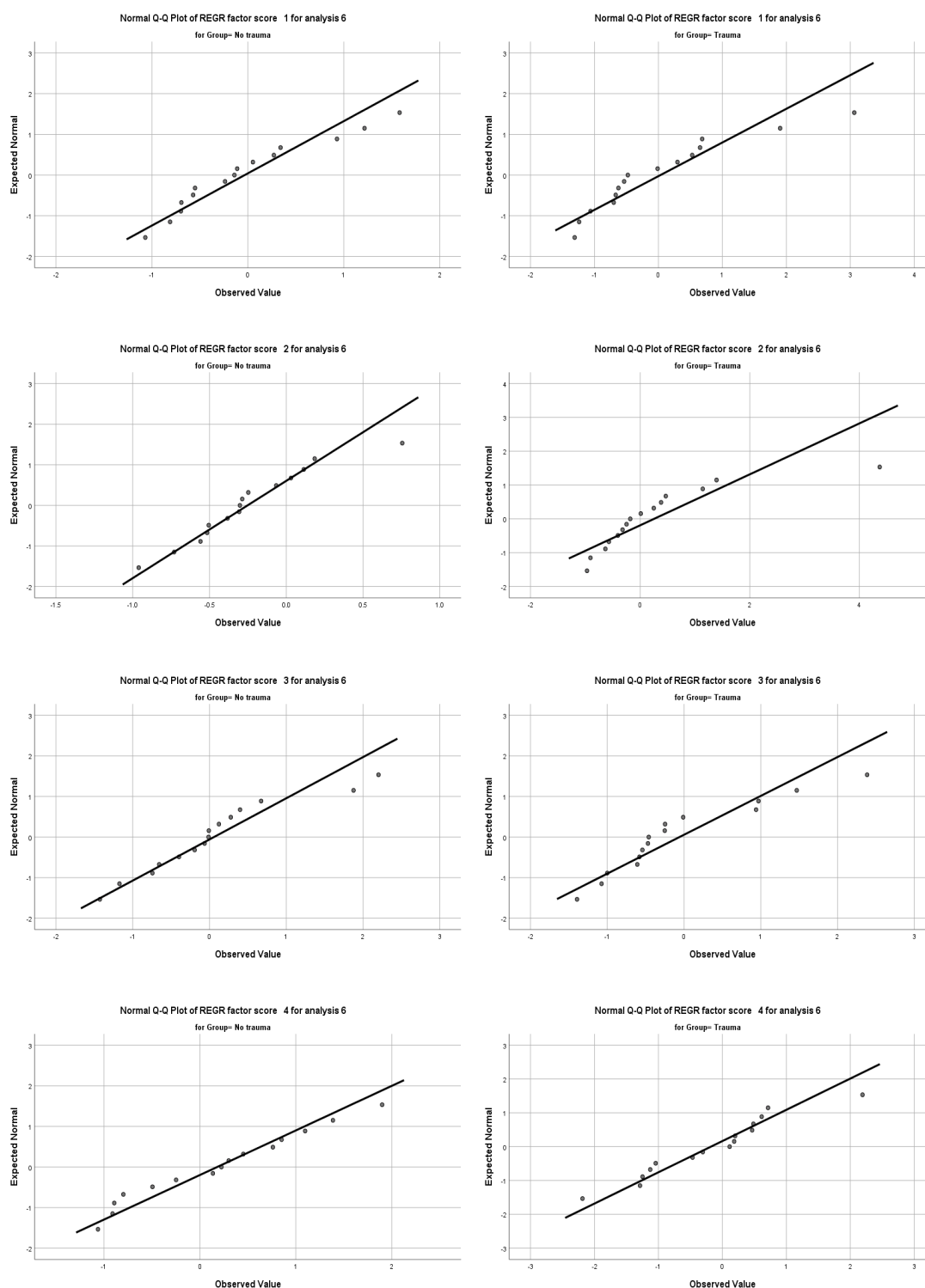


Figure 7. Q-Q plots of four components in the High Beta band for both the control and trauma groups.

4.4. Group Comparisons of qEEG-Derived Components

Group comparisons were conducted using an independent sample *t*-test to examine whether participants in the severe-trauma group differed from participants in the no-trauma group in qEEG-derived component scores. For components that did not meet these assumptions, the results were interpreted cautiously, and non-parametric alternatives were considered. Both the descriptive table and the independent sample *t*-test results table were displayed underneath (see Table 6). The descriptive table showed that the means for the control group have slightly higher positive scores compared to the trauma group, while the

trauma group shows equivalent negative mean scores, which reflects the z-score nature of the PCA. As the outputs of the PCA were standardized into z-scores before performing the PCA, to remove the scale effects and allow direct comparison across participants and electrode placements [62,66,67]. This standardization data was around a mean of zero, meaning positive and negative component scores represent deviations above and below the group average, respectively. Therefore, the observed opposite mean values are a natural reflection of the z-score normalization and do not indicate data reversal or error, but rather reflect the activation differences around the standardized mean [68].

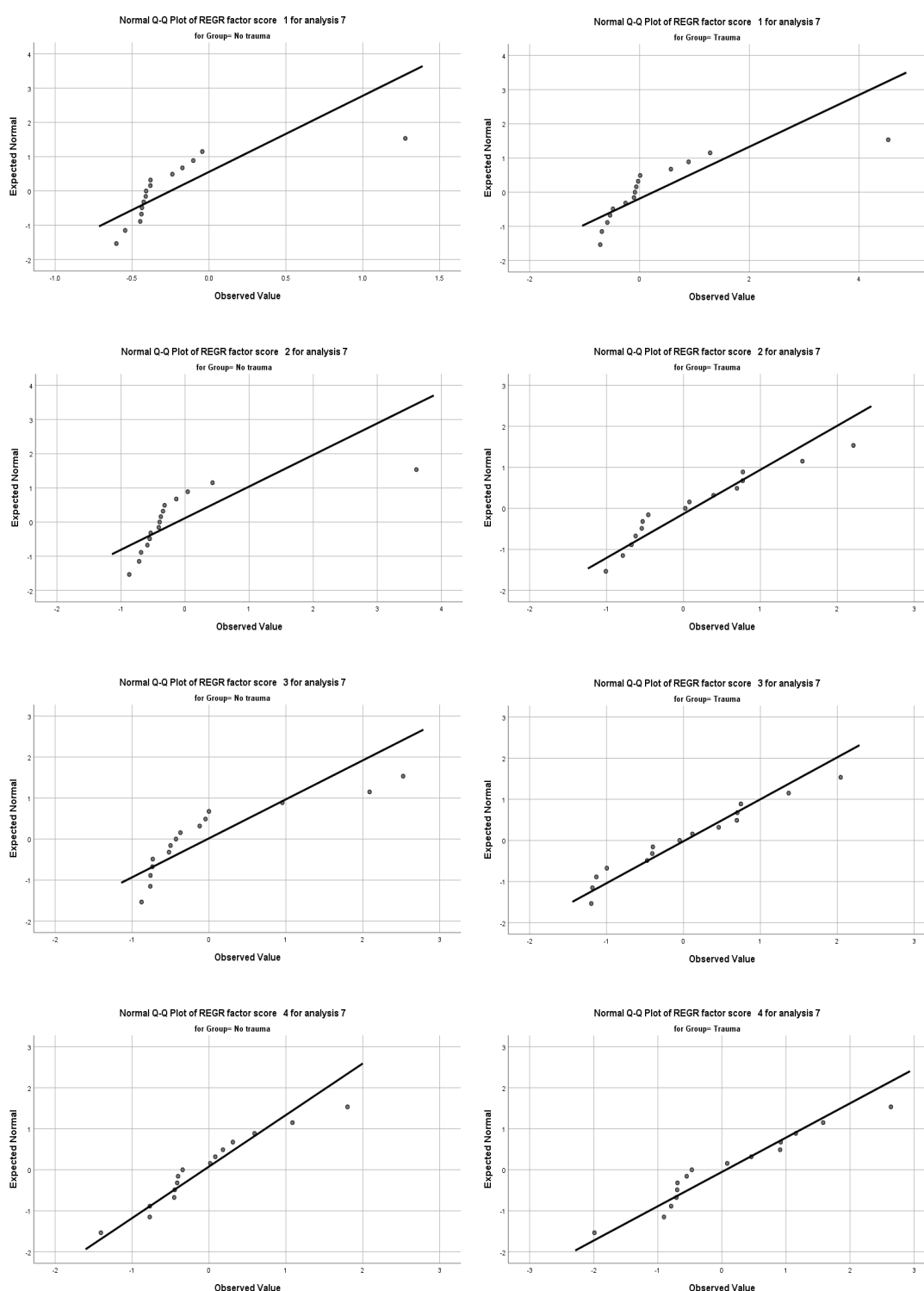


Figure 8. Q-Q plots of four components in the Gamma band for both the control and trauma groups.

Table 6. Descriptive statistics for independent-sample *t*-test results.

Power Band	Component	Group	Descriptive		<i>t</i> -Test		
			Mean	SD	<i>t</i>	df	Sig.
Delta	1	No trauma	0.227	1.052	1.253	28	0.694
		Trauma	−0.227	0.924			
	2	No trauma	−0.009	0.862	−0.051	28	0.295
		Trauma	0.009	1.153			
	3	No trauma	0.190	0.859	1.041	28	0.296
		Trauma	−0.190	1.121			
	4	No trauma	0.135	1.027	0.735	28	0.444
		Trauma	−0.135	0.989			
Theta	1	No trauma	0.069	1.067	0.371	28	0.899
		Trauma	−0.069	0.960			
	2	No trauma	0.184	0.785	1.006	28	0.288
		Trauma	−0.184	1.176			
Alpha	1	No trauma	−0.139	0.703	−0.758	28	0.050
		Trauma	0.139	1.239			
	2	No trauma	0.100	0.825	0.543	28	0.437
		Trauma	−0.100	1.170			
Low Beta	1	No trauma	−0.137	0.606	−0.745	28	0.050
		Trauma	0.137	1.290			
	2	No trauma	0.317	1.050	1.805	28	0.779
		Trauma	−0.317	0.868			
Beta	1	No trauma	0.011	0.654	0.060	28	0.016
		Trauma	−0.011	1.282			
	2	No trauma	0.112	0.899	0.609	28	0.297
		Trauma	−0.112	10.112			
	3	No trauma	−0.259	0.473	−1.445	28	0.029
		Trauma	0.259	1.305			
High Beta	1	No trauma	−0.033	0.779	−0.176	28	0.175
		Trauma	0.033	1.209			
	2	No trauma	−0.252	0.417	−1.401	28	0.041
		Trauma	0.252	1.327			
	3	No trauma	0.058	0.986	0.315	28	0.641
		Trauma	−0.058	1.045			
	4	No trauma	0.180	0.911	0.986	28	0.576
		Trauma	−0.180	1.083			
Gamma	1	No trauma	−0.250	0.450	−1.394	28	0.044
		Trauma	0.250	1.317			
	2	No trauma	−0.124	1.082	−0.673	28	0.544
		Trauma	0.124	0.932			
	3	No trauma	−0.019	1.053	−0.103	28	0.840
		Trauma	0.019	0.981			
	4	No trauma	−0.062	0.796	−0.335	28	0.086
		Trauma	0.062	1.196			

The inferential results are presented in Table 6. Based on the verified statistical output, most PCA-derived components did not show statistically significant group differences, with all of their *p*-values being more than 0.05 [69]. However, group differences were observed in selected components within the Alpha, Low Beta, Beta, High Beta, and Gamma frequency bands. These findings suggest that severe childhood trauma exposure may be associated with differences in selected resting-state qEEG-derived components when compared with no reported childhood trauma.

However, these findings should be interpreted cautiously. First, the sample size was small, with only 15 participants in each group. Second, the sample had a substantial sex imbalance, with more female than male participants. Third, multiple comparisons were conducted across several PCA-derived components and frequency bands, increasing the risk of Type I error. Fourth, the Gamma band did not fully meet the normality assumption. Therefore, the findings should be treated as exploratory and should be verified in future studies using larger samples, balanced demographic characteristics, and appropriate correction for multiple comparisons.

5. Discussion

In this study, we assessed the relationship between individuals with and without the experience of childhood trauma. The results showed that individuals with severe levels of childhood trauma exhibited differences in brainwave patterns, particularly (1) increased activity in the Alpha band in F3, F4, Fz, C3, C4, P3, and P4, (2) increased activity in the Low Beta band in F3, F4, C3, T3, P3, and P4, (3) decreased activity in the Beta band in F3, C3, Cz, P3, and P4, (4) increased activity in the Beta band in F7, Fz, F8, and F4, (5) increased activity in the High Beta band in F7, Fz, F4, F8, and T5, and (6) increased activity in the Gamma band in F7, F8, Fz, F4, and T5.

In this study, we found that there were band-specific local differences in brainwave activity between individuals with and without childhood trauma. The hypothesis in this study, which predicted that there are significant local differences in neural activity between individuals with and without childhood trauma as assessed by the CTQ-SF, was supported. The independent-samples *t*-test conducted on PCA components indicates group differences across several frequency bands, particularly Alpha, Low Beta, Beta, High Beta, and Gamma. These findings indicate that childhood trauma exposure may be associated with differences in brainwave activity patterns in specific cortical regions.

The Alpha band showed an increased level of activity, particularly in areas of F3, F4, Fz, C3, C4, P3, and P4. These findings were consistent with the previous study conducted by Laney and Nooner, who reported that individuals with childhood trauma exhibit an increase in their Alpha activity level, particularly in their frontal, central, and parietal regions [46]. However, it was inconsistent with the past research by Howells and colleagues, as well as Lee and colleagues, who reported that trauma-affected individuals would have a reduction in their Alpha activity [41,43]. Alpha activity is often associated with relaxation and inhibitory processes in the brain. An increased level of the Alpha band in regions such as the frontal, central, and parietal regions indicates cortical inhibition activity. In these regions, increased Alpha activity serves as a filter in filtering out irrelevant information and enhances the brain's focus on relevant stimuli [70,71]. It suggests that individuals with childhood trauma may engage in inhibitory control as a coping mechanism to block the stimuli that may distract them, which aligns with the concept from the defense cascade model, particularly the faint stages, where individuals experience "shutdown" to escape from the undesirable situations or avoid irrelevant information. In addition, increased Alpha activity in the central and parietal regions has been reported to be associated with cognitive efficiency and maintaining working memory [72]. It can be used to explain that individuals with childhood trauma may exhibit greater cognitive effort or compensate for potential disruptions in processing information efficiently. The Alpha activity in the parietal regions plays a role in spatial attention and sensory integration [73], which suggests that individuals with childhood trauma may have heightened focus on internal cognitive processes or external stimuli, which could lead to an increased sensitivity to their surroundings, resulting in an overreaction to environmental cues or emotional stimuli.

Interestingly, this study found that the trauma group exhibited higher levels of Low Beta activity in the frontal (F3 and F4), central (C3), and parietal (P3 and P4) regions, with no similar studies mentioning any changes in the Low Beta band. The Low Beta band is often associated with the abilities of attention, arousal, and sensorimotor control. The past study has mentioned that the Low Beta band is positively correlated with reaction times, which means that higher activity levels of the Low Beta band are associated with slower reaction times [74]. This can be explained by the fact that individuals with childhood trauma may exhibit difficulties in effectively preparing for or initiating movements, which is supported by the first stage of the defense cascade model, the “freeze” response, as well as the activation of the dorsal vagal system in polyvagal theory. Both theories suggest that individuals may experience freeze or “shutdown” first when they perceive danger or a threat in their surroundings [75–79].

A reduction in the Beta band was observed in the areas of F3, C3, Cz, P3, and Pz of trauma-affected individuals, which may indicate an experience of impaired cognitive processing and memory encoding, as these brain regions are crucial for integrating sensory information and regulating emotional responses. In trauma-affected individuals, the reduced Beta band activity in these areas suggests that their brain is struggling to manage the incoming information and emotional states efficiently, which could reflect an inability to properly suppress or filter out intrusive, trauma-related memories, leading to difficulties in attention, memory recall, and emotional regulation [80]. These findings are against the study by Lee and colleagues, who found elevated Beta band activity in those areas [43]. The reduced Beta band activity in the current study could indicate a state of hypervigilance or emotional dysregulation, where the brain’s cognitive resources prioritize processing the traumatic memories rather than focusing on present tasks. This could further explain the common cognitive impairments seen in individuals with childhood trauma, such as difficulties with concentration, memory, and managing emotional responses to stress.

While this study also discovered an increased activity in the Beta band in the areas of F7, Fz, F8, and F4, which is consistent with the study by Lee and colleagues, who mentioned that the hyperactivation in these areas demonstrates a pattern of frontal cortical hyperarousal that reflects significant neurophysiological and cognitive-emotional dysregulation [43]. The frontal regions of the brain are involved in attentional control and emotion regulation, and the hyperactivation in the Beta band may reflect a heightened state of alertness, resulting in difficulty filtering out emotional distractors. This could lead to cognitive overload and heightened emotional responses in situations involving stress or trauma reminders, contributing to persistent feelings of anxiety, irritability, or emotional instability [81]. This pattern of dysregulation may have a long-lasting impact on individuals with traumatic experiences, including persistent re-experiencing of traumatic memories and difficulty regulating emotional reactions. These alterations in brainwave patterns help in explaining why individuals with childhood trauma may exhibit altered neural patterns that persist into adulthood.

Furthermore, the trauma group exhibits a high activity of the High Beta band in F7, Fz, F4, F8, and T5, and there are no studies that have used the qEEG to assess neural changes in individuals who have experienced childhood trauma, reporting any changes in the High Beta band. An elevated activity of the High Beta band in the frontal and temporal regions indicated heightened cognitive activation, increased neural processing, and potential hyperexcitability or hypervigilance states. High Beta activity is particularly associated with an increase in attention, emotional processing, and threat detection, suggesting that the higher activity of the High Beta band may reflect a heightened state of vigilance and arousal in response to childhood trauma-related stimuli. The past study has mentioned that an elevated High Beta activity in temporal regions is correlated with heightened amygdala

activation, which is involved in emotional processing and threat detection; therefore, heightened activity in the High Beta band may result in maladaptive emotional responses such as an increased level of an individual's anxiety, stress, and emotional instability [82]. It may also reflect the neurophysiological state where the brain is constantly prepared for potential danger, even in the absence of immediate threats, contributing to a constant state of stress [83]. Over time, this chronic heightened state of alertness can alter the neural circuits of the individuals who have experienced childhood trauma, leading to the persistent overactivation in their High Beta band. This constant vigilance, combined with difficulty in regulating emotional responses, may explain why individuals with childhood trauma exhibit an increase in their High Beta patterns.

An increased activity level of the Gamma band in the trauma group was shown in the areas of F7, F8, Fz, F4, and T5, which are the regions that involve emotional regulation, cognitive functions, and stress response. This result was consistent with Lee and colleagues, who mentioned that individuals who have experienced childhood trauma, as assessed by the CTQ-SF, showed an increase in the Gamma band [43]. One of the primary factors of the heightened Gamma activity is chronic hyperarousal, where the brain remains in a state of heightened vigilance, continuously scanning for potential threats, and the constant hyperactivity of the amygdala further amplifies the Gamma bands that are associated with threat detection and emotional processing [84]. This suggests that individuals with childhood trauma may be oversensitive to their surroundings, which leads them to a heightened stress and anxiety level, thus contributing to the elevated activity level of the Gamma band. Additionally, there is a study that supports the sensory hypothesis of PTSD, which proposes that sensory hyperactivity, particularly in the frontal regions, is a characteristic of individuals with PTSD [85], while the current study provides evidence that sensory hyperactivity may also occur in individuals who do not have a formal PTSD diagnosis.

5.1. Limitations and Recommendations

This study has several limitations. First, their childhood trauma severity level was based on self-report, whose accuracy may be influenced by several factors, such as false memory, emotional state, or current psychological conditions [40]. Second, the sample size for this study is relatively small, which may limit statistical power and the generalizability of the findings. Third, participants' current stress, anxiety levels, sleep quality, and other physiological or lifestyle factors were not controlled, which may influence qEEG results. Lastly, this study only included resting-state EEG conditions (eyes-closed and eyes-open) in the final analysis, while task-based recordings were excluded to maintain methodological consistency.

Therefore, further study was encouraged to employ a larger sample size in order to make the results more generalizable and conduct an interview session to provide a more comprehensive and accurate assessment of the participants' trauma histories, as well as employ tools to measure their current stress levels, as the study has found that acute stress is associated with higher activation of Beta power [86]. Therefore, measuring the current stress level may reduce the variables that may affect the findings and provide a more accurate interpretation of the relationship between childhood trauma and brainwave activity.

5.2. Conclusions

In conclusion, this study found that there are band-specific local differences in brainwave activity between individuals with and without childhood trauma, particularly in Alpha, Low Beta, Beta, High Beta, and Gamma bands. These findings suggest that child-

hood trauma exposure may be associated with differences in neural activity patterns. Despite some limitations, such as the reliance on self-report questionnaires and a small sample size, this study suggests that qEEG may have potential for contributing to the understanding of trauma-related neural differences, even in individuals without a formal PTSD diagnosis. Future research should address these limitations by incorporating objective measures, increasing sample size, and considering participants' stress levels. These improvements would further enhance our understanding of the neurophysiological impact of childhood trauma and contribute to better diagnostic and therapeutic strategies. More research is required in this field to further investigate potential associations between neurofeedback and neural indicators of trauma-related disorders.

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